PROTOTYPE SPACECRAFT FIRE EXTINGUISHER EVALUATION

by

W.R. Herrera

FINAL REPORT

Contract NAS 9-7727
SwRI Project No. 01-2310

Prepared for

National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas 77058

April 18, 1968

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John T. Goodwin, Director
Department of Chemistry and
Chemical Engineering

ABSTRACT

Two prototype extinguishers charged with the extinguishment agent used in both the prototype and flight hardware were supplied to MSC for shelf life tests.

The experimental studies in this report demonstrated the ability of the extinguishment agent to rapidly extinguish fires in pure oxygen at pressures up to 20.0 psia.

There was no indication of decomposition of the Freon-12 when the extinguishment agent was applied to fires in pure oxygen at 6.2, 15.0, and 20.0 psia.

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I. INTRODUCTION

A spacecraft fire extinguisher concept utilizing an aqueous gel foam was developed by Southwest Research Institute under NASA Contract No. NAS 9-6876, and prototype extinguishers were designed, fabricated and evaluated by the Institute under NASA Contract No. NAS 9-7585. Although aqueous gel foams evaluated for apparent acute toxicity and effectiveness in atmospheric and subatmospheric pure oxygen under Contract No. NAS 9-6876 are quite similar to the particular foam being used in the prototype units, verification tests of the present gel foam with respect to toxicity and to extinguishing effectiveness in 20 psia pure oxygen had to be conducted and documented. Also, since no information is available on the shelf life of the extinguishers, additional prototype units were required at MSC for shelf life determination. This program was conducted to provide the desired services and hardware cited above.

II. PROGRAM

A. Prototype Extinguishers

Two prototype extinguishers, charged with the extinguishment agent used in both the prototype and flight hardware, were supplied to MSC for shelf life tests. Components, such as the handle, were omitted from both units when such components had no effect on the shelf life determination. A detailed test procedure for determining the shelf life of the units is submitted as an Appendix to this report.

B. Extinguishment Tests

The following foam formulation was prepared for use in the extinguishment and toxicity tests. This was the same formulation used in the prototype units produced under NASA Contract No. NAS 9-7585 and in the flight hardware being produced under contract to North American Rockwell Corporation.

Aqueous Gel:	1.5 pph Methocel MC-8000 1.5 pph Mearl Non Conductive 0.2 pph LMA (Mona) 0.5 pph Tergitol TMN
Freon:	Freon-12 in 1 : 4 weight ratio with aqueous gel

For the purposes of these tests, the foam material was charged in a pressure vessel without an expulsion bellows.

Duplicate extinguishment tests were conducted in 100% oxygen at 6.2, 15.0 and 20.0 psia. "Base-line" runs without extinguishment

indicated that the test specimen burned vigorously during the first 30 seconds. Accordingly, it was decided to introduce the foam at 20 seconds after ignition to provide extreme conditions. In all the tests, the test specimen was rapidly extinguished by the foam. Although extinguishment at 6.2 and 15.0 psia was not a contract requirement, it was observed in conjunction with the toxicity study and reported as a matter of information.

C. Toxicity Study

Toxicity experiments were conducted concurrently with the 6.2, 15.0 and 20.0 psia extinguishment tests, as shown in Tables I, II, and III, respectively. Polyethylene and RTV-102 were selected as the test specimen materials; Teflon or other halogen-containing fuel materials would have interfered with the interpretation of combustion products, since halogen compounds other than Freon-12 would be an indication of decomposition of the Freon.

The combustible samples were loops consisting of three 10" segments of 18 ga. polyethylene-coated wire inside an 11" segment of 5/16" O.D. heat-shrinkable polyethylene sleeve and three 1/2" segments of RTV-102 located at 3-1/3" intervals along the sleeve. The test specimens were mounted vertically in a 5" x 6" x 4" simulated electronics module which was placed in a 1.5 cu. ft. vacuum oven. After reaching the desired pressure

of pure oxygen, the oven atmosphere was steadily withdrawn for sampling with a corresponding make-up of pure oxygen. A hot wire ignition source was provided, and foam was injected into the simulated electronics module.

Gas chromatography was used to determine carbon dioxide and Freon-12 and to scan for extraneous peaks which could have been attributed to decomposition of the extinguishment agent. Carbon monoxide was determined by an M.S.A. Carbon Monoxide Detector. Infrared spectra were run to supplement the gas chromatographic analyses and, if applicable, to identify peaks which could have been attributed to extinguishment agent decomposition.

Comparison of the gas chromatographic analyses of the "base-line" combustion products and those resulting from the extinguishment tests did not reveal any peaks which would indicate decomposition of Freon-12.

Infrared analyses of gas samples resulting from the "base-line" burning of the specimens indicated the presence of carbon dioxide (CO_2) and traces of carbon monoxide (CO) and acetylene ($HC \equiv CH$). Samples resulting from the extinguished specimens contained CO_2 and Freon-12 and traces of CO and $HC \equiv CH$. There was no indication that any decomposition of Freon-12 had occurred.

The total volume of Freon-12 that would be released from four cubic feet of foam at 6.2 psia would be approximately 5.08 cubic feet. A crew confined in a volume of 300 cubic feet would be exposed to 1.66 percent by volume Freon-12 vapors. In data[1] provided by Underwriters' Laboratories on the classification of comparative life hazard of gases and vapors, Freon-12 is classified as being among "Gases or vapors which in concentrations up to at least about 20 percent by volume for durations of exposure of the order of 2 hours do not appear to produce injury".

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[1] Technical Bulletin No. B-2, Freon, E. I. duPont de Nemours and Co.

III. CONCLUSIONS

The experimental studies have demonstrated the effectiveness of the extinguishment agent on fires in pure oxygen at pressures up to 20.0 psia.

The studies indicate no decomposition of the Freon-12 when the extinguishment agent is applied to fires in pure oxygen at 6.2, 15.0, and 20.0 psia. It is concluded that the cooling afforded by the high percentage of water in the extinguishment agent is sufficient to prevent thermal decomposition of the Freon-12. This coupled with the reported low toxicity level of Freon-12 vapor indicates no reason for concern regarding this component.

The carbon dioxide and carbon monoxide concentrations are obviously related to the amount of fuel which is consumed in the fire; hazard from these gases would be a function of the time required for detection and extinguishment of a fire. The same would be true of combustion products of other types of fuels such as halocarbons.

In summary, there is no indication that the extinguishment agent presents an obvious toxicity hazard, although the experimental program cannot be considered a true toxicity study.

TABLE I. COMBUSTION PRODUCTS AT 6.2 PSIA

Oxygen Make-Up: 0.115 SCFM at Test Pressure

Run No.	Test Conditions and Comments	Analysis of Exit Stream			
		Time (min)	CO[1] (%)	CO_2[2] (%)	F-12[2] (%)
1	Total combustion at 6.2 psia. Specimen burned vigorously for about 30 sec, then glowed until it reignited itself at around 240 sec. Sample completely consumed after 300 sec. Wt. loss = 4.81g.	0.5	0.06	6.68	N/A
		1.0	0.23	12.76	
		2.0	0.12	12.97	
		4.5	0.23	21.02	
		6.0	0.12	17.98	
		8.0	0.12	16.45	
		10.0	0.12	10.69	
		12.0	0.12	7.93	
		14.0	0.09	8.42	
2	Total combustion at 6.2 psia. Specimen burned vigorously for about 30 sec, then glowed until it reignited itself at around 200 sec. Sample completely consumed after 300 sec. Wt. loss = 4.59g.	0.5	0.05	6.21	N/A
		1.0	0.12	7.84	
		2.0	0.12	10.69	
		4.5	0.12	20.25	
		6.0	0.12	20.62	
		8.0	0.12	14.71	
		10.0	0.12	10.88	
		12.0	0.12	7.75	
		14.0	0.09	5.36	
3	Burning and extinguishing at 6.2 psia. Sample was ignited and allowed to burn for 20 sec before the foam was introduced. Wt. of foam used = 50.0g. Wt. loss = 0.54g.	0.5	0.05	3.20	5.13
		1.0	0.05	3.43	7.52
		2.0	-	3.59	7.70
		4.5	0.006	1.67	5.96
		6.0	0.006	1.21	4.59
		8.0	0.006	0.86	3.29
		10.0	0.005	0.37	2.48
		12.0	-	0.37	1.93
		14.0	-	0.28	1.23
4	Burning and extinguishing at 6.2 psia. Sample was ignited and allowed to burn for 20 sec before the foam was introduced. Wt. of foam used = 56.0g. Wt. loss = 0.30g.	0.5	0.05	2.20	4.85
		1.0	0.03	1.58	4.94
		2.0	0.012	1.90	7.00
		4.5	0.012	0.95	3.29
		6.0	0.006	0.67	2.97
		8.0	0.006	0.60	2.83
		10.0	0.005	0.44	2.02
		12.0	-	0.32	1.51
		14.0	-	0.28	1.18

1 Determined by M.S.A. Carbon Monoxide Detector.

2 Determined by gas chromatography.

TABLE II. COMBUSTION PRODUCTS AT 15.0 PSIA

Oxygen Make-Up: 0.135 SCFM Flowing at Test Pressure
Exit Stream Flow Rate: 0.139 SCFM

Run No.	Test Conditions and Comments	Analysis of Exit Stream			
		Time (min)	CO[1] (%)	CO_2[2] (%)	F-12[2] (%)
5	Total combustion at 15.0 psia. Specimen totally consumed in 80 sec. Pressure increased to 15.4 psia during the first 45 sec of combustion, then dropped to test pressure after this period. Wt. loss = 5.00g.	0.5	0.05	8.16	N/A
		1.0	0.10	10.88	
		2.0	0.07	13.76	
		3.0	0.05	11.45	
		4.5	0.10	10.46	
		6.0	0.10	7.91	
		8.0	0.07	6.59	
		10.0	0.07	4.94	
		12.0	0.10	3.71	
		14.0	0.10	2.72	
6	Total combustion at 15.0 psia. Specimen totally consumed in 90 sec. Pressure increased to 15.4 psia during the first 45 sec of combustion, then dropped to test pressure after this period. Wt. loss = 5.27g.	0.5	0.07	13.84	N/A
		1.0	0.02	14.17	
		2.0	0.10	14.34	
		3.0	0.10	11.54	
		4.5	0.05	10.38	
		6.0	0.05	5.93	
		8.0	0.06	6.02	
		10.0	0.08	4.37	
		12.0	0.07	3.09	
		14.0	0.07	2.31	
8	Burning and extinguishing at 15.0 psia. Sample was ignited and allowed to burn for 20 sec before the foam was introduced. Pressure increased to 15.6 psia after ignition and then to 16.4 psia when the foam was introduced. Returned to test pressure after 45 sec. Wt. of foam used = 59.0g. Wt. loss = 2.27g.	0.5	0.10	9.56	0.67
		1.0	0.05	7.66	2.80
		2.0	0.05	5.27	3.04
		3.0	0.04	4.37	2.64
		4.5	0.04	4.20	2.84
		6.0	0.04	2.43	1.94
		8.0	0.04	2.27	1.66
		10.0	0.02	1.65	1.54
		12.0	0.02	1.24	1.30
		14.0	0.01	1.03	1.18
13	Burning and extinguishing at 15.0 psia. Sample was ignited and allowed to burn for 20 sec before the foam was introduced. Pressure increased to 15.9 psia after ignition and then to 16.7 psia when the foam was introduced. Returned to test pressure after 45 sec. Wt. of foam used = 71.0g. Wt. loss = 2.75g.	0.5	0.06	7.83	2.17
		1.0	0.04	8.73	2.96
		2.0	0.04	6.80	2.69
		3.0	0.04	6.43	2.61
		4.5	0.04	5.81	2.65
		6.0	0.04	5.03	2.53
		8.0	0.03	4.61	2.78
		10.0	0.03	3.67	2.90
		12.0	0.02	3.01	2.73
		14.0	0.02	2.60	2.65

[1] Determined by M.S.A. Carbon Monoxide Detector.
[2] Determined by gas chromatography

TABLE III. COMBUSTION PRODUCTS AT 20.0 PSIA

Oxygen Make-Up: 0.091 SCFM Flowing at Test Pressure
Exit Stream Flow Rate: 0.124 SCFM

Run No.	Test Conditions and Comments	Analysis of Exit Stream			
		Time (min)	CO[1] (%)	CO_2[2] (%)	F-12[2] (%)
9	Total combustion at 20.0 psia. Specimen totally consumed in 55 sec. Pressure increased to 21.3 psia during the first 45 sec of combustion, then dropped to test pressure after this period. Wt. loss = 5.27g.	0.5	0.05	13.51	N/A
		1.0	0.08	15.82	
		2.0	0.04	15.82	
		3.0	0.04	12.03	
		4.5	0.06	10.71	
		6.0	0.04	9.06	
		8.0	0.02	7.25	
		10.0	0.02	6.18	
		12.0	0.02	5.36	
		14.0	0.02	4.53	
10	Total combustion at 20.0 psia. Specimen totally consumed in 55 sec. Pressure increased to 21.2 psia during first 45 sec of combustion, then dropped to test pressure after this period. Wt. loss = 4.87g.	0.5	0.02	13.68	N/A
		1.0	0.04	14.34	
		2.0	0.06	12.52	
		3.0	0.08	11.04	
		4.5	0.04	9.72	
		6.0	0.04	8.24	
		8.0	0.03	7.91	
		10.0	0.04	6.59	
		12.0	0.04	5.69	
		14.0	0.04	5.03	
11	Burning and extinguishing at 20.0 psia. Sample was ignited and allowed to burn for 20 sec before the foam was introduced. Pressure increased to 21.4 psia after ignition and then to 22.4 psia when the foam was introduced. Returned to test pressure after 45 sec Wt. of foam used = 77.0g. Wt. loss = 3.6g.	0.5	0.05	8.73	1.13
		1.0	0.04	7.58	1.98
		2.0	0.03	6.84	2.09
		3.0	0.04	6.18	1.90
		4.5	0.04	5.27	1.70
		6.0	0.02	4.61	1.58
		8.0	0.02	3.96	1.38
		10.0	0.02	3.38	1.22
		12.0	0.02	2.64	1.11
		14.0	0.02	2.51	1.18
12	Burning and extinguishing at 20.0 psia. Sample was ignited and allowed to burn for 20 sec before the foam was introduced. Pressure increased to 21.4 psia after ignition and then to 22.7 psia when the foam was introduced. Returned to test pressure for 45 sec. Wt. of foam used = 85.0g. Wt. loss = 3.12g.	0.5	0.03	6.59	1.90
		1.0	0.04	8.08	1.90
		2.0	0.04	7.50	2.25
		3.0	0.03	6.67	2.11
		4.5	0.03	5.93	1.94
		6.0	0.04	4.78	1.66
		8.0	0.03	4.45	1.62
		10.0	0.02	3.96	1.46
		12.0	0.02	3.17	1.34
		14.0	0.02	2.72	1.26

1 Determined by M.S.A. Carbon Monoxide Detector.
2 Determined by gas chromatography.

APPENDIX A

"Procedures for Shelf Life Evaluation of the
Fire Extinguishment Agent Used in the
Prototype Extinguisher P/N 211401-01"

PROCEDURES FOR SHELF LIFE EVALUATION OF THE FIRE EXTINGUISHMENT AGENT USED IN PROTOTYPE EXTINGUISHER P/N 211401-01

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1.0 INTRODUCTION

This specification establishes the procedures for evaluating the shelf life of the prototype extinguishment agent used in the prototype fire extinguisher (P/N 211401-01).

2.0 EQUIPMENT AND MATERIALS

The following equipment and materials, or equivalent equipment and materials, are approved for use in the performance of the tests outlined in this document.

(1) Paint Shaker, Red Devil, Model No. 30 (modified), 240 $\pm$ 40 cycles/min.

(2) Nominal 400 ml Beaker, Calibrated to Establish Brim Level Volume.

(3) Balance, Triple Beam, W. H. Curtin, Cat. No. 1955, 0 to 1610 grams, Accuracy 0.1 gram, Calibration Interval 180 Days.

3.0 PROCEDURES

This section lists the procedures to be used during the tests designed to evaluate the shelf life of the prototype extinguishment agent.

(1) Perform these measurements on a monthly basis.

(2) Clamp the prototype fire extinguisher in the paint shaker and agitate for 1 hour at a speed of 240 $\pm$ 40 cycles per minute.

(3) The test article discharge valve shall be uncapped and a rigid nozzle attached.

(4) Perform a foam density determination (for comparison with the first base line density established at the beginning of this study), with the extinguisher discharged in the upright position.

(5) A calibrated 400 ml beaker will be filled with foam and struck level with a straight edge.

(6) The filled beaker will be weighed to 0.1 gram accuracy as quickly as possible.

(7) Inspect the foam for any discoloration and/or non-uniformity.

(8) Foam density will be calculated in grams per milliliter.

(9) The rigid nozzle will be detached and the cap replaced on the test article valve for storage until the next measurement is made.

(10) A gross change in foam density or cell uniformity or a discoloration of the foam is an indication of degradation of the extinguishment agent.